TECHNOLOGICAL FORECASTING AND MANAGEMENT ACTION

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THESIS

TECHNOLOGICAL FORECASTING
AND MANAGEMENT ACTION

by

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This thesis addresses the relationship between technological forecasting, technology assessment, and technology transfer, and presents the viewpoints of authors in the subject areas. It indicates how technology originates, is planned for and finally transfers into ultimate use.

Technological Forecasting
and
Management Action

by

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I. INTRODUCTION

A. BACKGROUND AND SCOPE OF THE STUDY

To plan properly requires a knowledge of future opportunities and conditions. In this time of rapid technological change, powerful forecasting techniques are required to make adequate forecasts. Such techniques do exist. Using them to take advantage of future opportunities is known as technological forecasting. The relatively youthful art of Technological Forecasting may in current application appear to be a separate discipline, interacting with planning from an independent outside position.

A discipline, or would-be discipline, is beset with separate problems. Are its assumptions valid or realistic? Are its methods reliable? Are its results reproducible? And what significant impact could be expected from merging technological forecasting to research and development (R & D) and integrative management policies and planning.

The purpose of this study is to investigate the creative effects of technological forecasting on the process of management, and to give better understanding of the effects of technological forecasting on business processes. This will be done by drawing together views and opinions of experts and

specialists in the technology forecasting field. In order to provide a foundation for the study an extensive review of the relevant literature was undertaken. The Naval Postgraduate School library was used as the primary source of materials for the review of the literature.

B. OBJECTIVES

Specific questions which this research attempts to answer are the following:

1. What is the relationship between technology, technological change, forecasting, management views, and the techniques associated with these subjects?
2. What is Technological Forecasting and what is the importance, purpose, and extent of its practice?
3. What are the methodologies and procedures of technological forecasting used to encourage dynamic integrative planning, and the R & D procedures relating to the type, size, nature, and degree of technological intensiveness?
4. Can technological forecasting assist a corporation in identifying future technological opportunities and threats?

Question one is addressed in Chapters II and III. Chapter II presents the general and technological background and

discusses the advantages of recognition of technology, and the technological environment. Chapter III reviews forecasting and the factors which may be considered in planning a future action.

Chapter IV addresses question two, and presents the fundamental concepts of technological forecasting, and defines it.

Chapter V is the main part of study and deals with those methodologies and procedures of technological forecasting relating to question three.

The conclusions and summaries reached in the study are also presented as Chapter VI.

Appendix A treats the definitions of some important words and concepts used in this study.

Appendix B presents technological forecasting techniques with emphasis on the Delphi technique concept.

II. BACKGROUND

A. GENERAL BACKGROUND

The process by which technical advances, ideas, or inventions are translated into products, processes, or services has become of increasing concern in recent years. There is widespread agreement, that managers in companies realize, that no matter how experienced individuals or committees may be, they cannot make decisions related to complicated processes of technical advancement at a corporate level merely on the basis of intuition. Technology is changing so rapidly that it is necessary to be aware of what is going on not only in a specific field of interest, but also in complementary and competitive fields, and in the whole social-political-economic environment. If a decision has been made on an intuitive basis the rationale or justification for it is lost and cannot be repeated or explained. Additionally, without some formalized method of sifting and weighing all the information related to technological advance, the decision may not be effective.

In effect, the techniques provide the tools whereby the technical knowledge and judgment of the forecaster can be applied to logical, systematic thinking about the pattern of development of a particular technology.

A distinction should be made between technological forecasting and planning. "Technological forecasting differs from technological planning in that forecasters attempt to prodict what will happen technologically within the economy, whereas the planner is concerned primarily with goal setting. The advocaters of technological forecasting believe that to make an economic forecast without also trying to gauge the impact of technical change is to leave out a vital dimension necessary for planning." /Ref. 1/.

The concept of technological forecasting is beginning to take its place as a promising management tool, to be integrated with long-term planning, market forecasting, and financial forecasting. Technological forecasting is not a panacea; it describes; not what the future will be but only what the future could be /Ref. 2/. It does not take away any of management's decision-making power; it merely helps those who make decisions to assess the consequences more adequately. It may be somewhat irrelevant for some companies, but it may be useful, even if it cannot provide ready answers for all problems.

This thesis will try to show that forecasting can be useful in providing information on which resource allocation decisions can be based. It will attempt to provide a better appreciation of the value of technological forecasting for virtually any technology, especially when one considers James B. Quinn's

broad definition of technology. He states: "The fact is that a 'Technology' is not a single immutable piece of hardware or bit of chemistry. It is simply knowledge -- knowledge of physical relationship systematically applied to the useful arts. This knowledge can vary continuously over time. It can range from the initial glimmerings of how a basic phenomenon can be applied to the solution of a practical problem to an end product, device, or production machine in a mature operating system." [Ref. 3].

An approach to the identification of threats and opportunities helps to reveal policy options at all levels of broad business strategy. William L. Swager states: "Technological forecasts are essential to the development of realistic strategic plans. However many companies' efforts to use technological forecasting methods have been less than successful for two reasons: First, forecasts of social, economic, and political trends and events have not been sufficiently integrated with those of technological events and trends, and, second, the technological forecasting activity has tended to be divorced from either business or technical planning." [Ref. 4]. The integration efforts have not been notably successful, simply because the approach to the identification of business threats and opportunities is as much a process as it is a method.

An understanding of the phenomena of technological change, and which factors influence it, could be useful for identification of opportunities and threats. This understanding is one of the major requisites for credible technological forecasting. An approach to it follows.

B. TECHNOLOGICAL BACKGROUND

1. Meaning of Technology

Technology is society's pool of knowledge regarding the industrial arts. The technology existing at a given point of time sets limits on how much can be produced with given amounts of inputs [Ref. 5]. Technology can thus be equated with simple mechanical techniques. In a very broad sense, it can be thought of as the total body of knowledge known to man [Ref. 6].

According to Dubin, there are two general meanings for "technology."

"1. Tools, instruments, machines, and technical formulas whose employment is necessary to its performance; and

2. The body of ideas which express the goals of the work, its functional importance, and the rationale for the methods employed." [Ref. 7].

Following this approach then, technology can be defined as mechanical techniques and abstract knowledge that are employed by people to help attain organizational objectives. Luthans

states that this concept of technology and its relationship with organizations can be universally applied to all types of organizations [Ref. 6].

2. Technological Change

Mansfield considers technological change to be the advance of technology, such advance often taking the form of new methods of producing existing products or new techniques of organization, marketing, and management [Ref. 5].

Morton believes that the survival of people and their institutions depends increasingly on innovation; the improvement of the old and the development of new capabilities and organizations [Ref. 8].

Technological change, therefore, like feedback in an electronic circuit, can work to stabilize the typical framework of the organization. It can also work to neutralize or disrupt, depending on the way management actions are perceived by the research workers.

According to Cetron, "Technological change is the link between the past state-of-the-art and its present and future states." [Ref. 9]. He believes that an understanding of technological change is required to develop plans and to institute controls that will direct the course of technological change in a manner which will be beneficial to the organization, and in the case of government R & D, to the general advantage of

the country. He states also, "since technology is the application of a body of knowledge to useful purposes, technological change then is the transfer of new knowledge from those who originate it to those who can apply it." [Ref. 9].

In this context the process of technological change is identified by Donald Schoen as having three major stages:

1. Invention: the creation of a new product or process.

2. Innovation: the introduction of that product or process into use.

3. Diffusion: the spread of the product or process beyond first use [Ref. 10].

As a practical matter, he points out, it is the diffusion of technology which is more amenable to forecasting than invention or innovation.

The above discussion indicates that technological change and its impact on society can be assessed and forecast. While this is true, the full range of social impact must be evaluated with acceptable standards of comparison. In this regard Becker states: "To say that we are going to make a technology assessment on a given subject implies that we have a standard of comparison which allows us to determine the worth or value of the technology under scrutiny." [Ref. 11]. The increasing rate of technological change, and rapidly growing rate of innovation

and diffusion, enhances the need for better assessment and forecasting of techniques for technology growth.

3. <u>Importance of Technology Assessment</u>

In microeconomic terms, the opportunity cost of resources directly affected by changes in technology is of prime interest to the environmentalists.

At the national level, the importance of assessment of technology has been widely discussed and gradually accepted. This is amplified by the fact that the ninety-second congress of the United States proposed legislation creating an office of technology assessment whose principal assignment would be to contract for studies that would provide congress with early warning concerning potential consequences of new technology, with analysis of alternative measures. The ninety-third congress established the format for national policy and priorities in science and technology. The Act was passed in October 1974 [Ref. 12].

Industrial technology forecasting is treated in the literature in a planning framework. "Modern planning increasingly assumes the character of a process of continuous search and modification, a process that needs technological forecasting to map out technological options and interactions and, at the same time, enhance the quality of forecasting by plotting alternative paths to link the future to present action." [Ref. 13].

Plans for the future include the estimate of a technology production function that relates development expenditure to technology improvement and cost reduction. Hence, it is important to foresee future possibilities as clearly as possible. This foresight is improved, when the nature of an advanced technology, and its impact on decision making processes are analysed and aided by the methodologies of technological assessment and technological forecasting.

In previous sections it has been noted that it is possible to evaluate technology in a given state by making some standard comparisons. This can be done by means of technology assessment.

What is technology assessment? "Technology assessment attempts to establish an early warning system to detect, control, and direct technological change and development so as to maximize the public good while minimizing the public ills. It is one of the new approaches to allocating scientific resources, establishing technological priorities, and seeking relevant alternatives to current technology." /Ref. 14/. This is one of the varieties of definitions so far offered for technology assessment.

Based on a number of definitions of technology assessment four requirements or elements that appear to be necessary for the conduct of assessment are identified by J. David Roessner and

Jeffrey Frey [Ref. 15]. Each of these requirements in turn implies the need for a variety of methods or techniques for its satisfaction. These include:

1. A description of the features of technology to be assessed.
2. A description of the existing physical and social setting into which the technology will be or has been introduced.
3. Identification of the anticipated consequences of the technology within the specified physical and social setting.
4. An evaluation of the consequences identified in the above step.

Methodologically the process of technology assessment involves the development of systematic procedures for the identification of important change elements and the indirect effects that may result from the introduction or redirection of a societal innovation [Ref. 16].

The third element of technology assessment "identification of the consequences of introducing new technology," calls for methods to predict future events of social, economic, environmental, and other consequences of new technology [Ref. 15]. According to Enzer technology assessment is frequently seen as

an extension of technological forecasting with the purpose of providing rationale for company policy [Ref. 16].

This concept will be further treated in later chapters on technological forecasting.

III. FORECASTING AND ITS MANAGERIAL APPLICATIONS

A. GENERAL FORECASTING

The general function of any forecast is to provide a base for present decisions. The information for the forecast describes and explains the alternatives for future development which are then evaluated from the point of view of the decision maker [Ref. 17]. Forecasts are thus prerequisites to planning, which is the process of making decisions which will tend to optimize the organization's future position despite random or organized changes in its future environment [Ref. 18].

Forecasting is oriented toward the identification of a desirable future as its final aim. It tries to reach this aim as effectively as possible; it starts from the understanding of some dynamic realities referred to by Steiner as premises [Ref. 17]. From the many phenomena to be investigated, desirable ones should be accepted as basic premises. These premises are major parts of the planning process. "Premise" means literally, that which goes before, previously set forth, or stated as introductory, postulated, or implied [Ref. 19].

In developing the planning premises, then, important choices are required for deciding which premises are applicable, which are most important, which should be studied in depth, and how

much resource should be used. According to J. B. Quinn, managers must imaginatively and systematically analyze potential opportunities and threats in the environment to see how they can best develop and exploit the organization's unique capacities and thus maintain its future dynamics. Following is the planning process given by Quinn [Ref. 18].

1. Analysis of the organization's concept position.
2. Forecasting future environment.
3. Evaluating alternative courses of action in terms of their potential future impact.
4. Choosing what is to be done.

If both the dynamic reality and the future desirability are recognized, general forecasting and especially technological forecasting could create new variables, which might modify the logical structure of decision making models.

B. TECHNOLOGICAL FORECASTING

Technological forecasting is emerging as an ingredient of the planning process which attempts to define the probable future capabilities of science and technology and to provide the information needed to guide technological development into efficient and fruitful paths. It requires effort from a planner to form a methodical base on which plans for progress toward achievement of certain goals desired in the future may be made [Ref. 9].

According to Cetron there are two principal ways to form this base. Firstly, the rapid growth of opportunity offered by many advances in science and technology necessitates a high selectivity on the part of the decision maker both at the level of the individual firm and on a national scale. Secondly, science and technology are increasingly recognized as influences in the transformation of society. Governments must therefore strive to foresee the impacts which technological developments are likely to have on future scoeity, and guide the application of new knowledge in the attainment of national goals [Ref. 20].

C. APPLICATION OF TECHNOLOGICAL FORECASTING

Proper cultivation and use of natural resources, need for environment control, and socio-economic difficulties, make it mandatory to seek and develop new and more effective methods for long-range planning and decision making [Ref. 14]. Additionally, risk and opportunities must be balanced in a manner appropriate to circumstances and objectives. A major problem besetting any organization, particularly if it is engaged in research and development, is knowing how best to allocate available resources. Never are there sufficient resources to fund every possible project envisioned by the research staff, or by management.

How, then, should projects be selected, and funds allocated? The first step in this process is to try to assess what the

future may hold in terms of the country's needs, competition, potential markets, international regulations and technologies. Currently, industrial research and development is important for the advancement of science, and contributes substantially to the use of science for peaceful purposes as well as for defense and survival. The rate of invention has accelerated almost to a point beyond comprehension of the human mind. The social reward from man's inventive genious is dependent upon the efficiency of utilization of research and development out-put [Ref. 21].

If man's ability to foresee and describe the future capabilities of science were to be more accurate, it would permit our society to become more productive and use our resources more economically. Also, the efficiency of utilization of R & D, could be enhanced. According to Cetron, as the cost of research and development continually increase, decision makers are forced to become increasingly cautious about approving requests for limited funds [Ref. 9]. A potential solution to the problem of resource allocation and effective use of R & D is to find more credible ways for forecasting of technological advancement.

Technological forecasting as will be described later, makes predictions associated with the design, production and use of devices, materials, and processes according to specified systems of reasoning. Forecasting, unless it is followed by innovation,

is meaningless. Morton describes technological innovation as: "Technological innovation is the process of perception or generation of relevant science, and its transformation into new and improved products and services for which people are willing to pay." He continues: "By paying attention to the purpose, to the parts, and to the couplings of the process, we can improve and accelerate the effectiveness of technological innovation." [Ref. 8].

A characteristic of technological innovation is that there is always a gap between the future needed technology and the technology which is available in a period of time. Cetron and Ralph state "After we have determined the technology which probably will be needed at some point of time and the technology which could then actually be available, the next problem is to define the tasks required to bridge the difference." [Ref. 2].

Traditionally this is the task of managers of R & D, as contrasted with other managers in industry and government. The reason is, "Where most managers must plan to meet technology change, the research and development managers additionally must plan technological change." [Ref. 9]. This is where you need innovative, creative and progressive management people. It is normally not enough that a technological forecast serve only general information. It must find its way into the formulation

of plans, programs, advanced designs, allocation policies, and other management functions [Ref. 9].

It is necessary to emphasize that in any discussion of technological change and innovation, it is important to establish the distinction between innovation and invention. According to Charles S. Shoup, Jr., "A piece of technology can be created-invented-and even patented, yet remain in the inventor's note-book with no impact whatsoever on society. Only when that invention is utilized in such a way as to have an economic impact on society is it termed an innovation." [Ref 22].

The efficiency of the R & D chain: Invention to innovation, depends to a larger degree than is often admitted on management's ability to motivate their most creative people in directions in which the results of their creativity are most liekly to be needed, and then put to use.

IV. THE FUNDAMENTAL CONCEPTS OF TECHNOLOGICAL FORECASTING

Success in forecasting technology can be improved if we understand the process by which technology emerges into social use. If we know the sources of technical concepts and those factors that support or inhibit its progress as it grows into physical reality and diffuses throughout society, we will have a better idea of what things to measure and what data to consider.

This chapter is devoted to clarifying the patterns and events in technological innovation processes, for better understanding of the factors which will shape technology.

A. FUTURE ORIENTED CORPORATIONS

Corporate decision making has always required both an orientation to the present and an orientation to the future. The former is necessary for stability and continuity, and the latter for change and adaptability. While both are essential, certain characteristics of today's external environment require much heavier reliance on a long-range perspective than was required in earlier times [Ref. 23].

For the short-range future it is sometimes possible to assume that the future will be very much like the past. Thus, plans may be built on the implied assumption that the economy, political environment, employee attitudes, membership

motivations and a host of other variables will remain almost constant. This can be a dangerous assumption, and is not generally followed by the more progressive corporations [Ref. 24]. "A future-oriented corporation is a corporation that takes responsibility for creating its own future whenever possible and adapting to change when necessary through a continuous process of future research, long-range planning, and objective setting." [Ref. 23].

Most decision makers evaluate their alternatives in terms of their goals, but it is obvious, that the future-oriented corporation's "goals" are in the future, which is uncertain. The scope for action is much greater than in the present, also it is possible for a decision maker and his staff, to turn accident into invention by imagining its possibilities, foreseeing second order and remote consequences, anticipating them, and planning how to exploit them [Ref. 25].

Although planning for the future is only one element in running a successful business, it is a key element. The decision maker must always review possible effects of different future events on the results of his activities. Also, according to sociologist Anthony Weiner who heads the Hudson Institute, "Trying to anticipate the future serves the same purpose as storing a spare tire in the trunk of your car. It prepares you to respond to contingencies."

B. PURPOSE, UTILITY AND DEFINITION OF TECHNOLOGICAL FORECASTING

Future-oriented corporate concepts begin with the assumption that the future is the most important resource available to any organization, and as with any resource, its use must be carefully managed and controlled.

According to Cetron [Ref. 9], to accomplish long-range R & D planning two fundamentals are prerequisite. First, one must have clearly in mind the future objectives to be achieved. Second, one must have a relatively clear knowledge of the anticipated state-of-the-art in the several supporting sciences and technologies, so that they may be exploited at an appropriate time to achieve those objectives. This is considered by some to be a technological innovation.

Bright states, "The process of technological innovation is a phrase intended to embrace those activities by which technical knowledge is translated into a physical reality and becomes used as a scale having substantial social impact." [Ref. 25]. This definition includes more than the act of innovation. Bright believes that it includes initiation of the technical idea and acquisition of necessary knowledge, its transformation into usable hardware (or a process), its introduction into society, and its diffusion and adaptation to the point where its impact is significant. This full process takes time, often years, and more often, decades.

Figure 1

TECHNOLOGY AND ITS
ENVIRONMENTAL INTERACTION

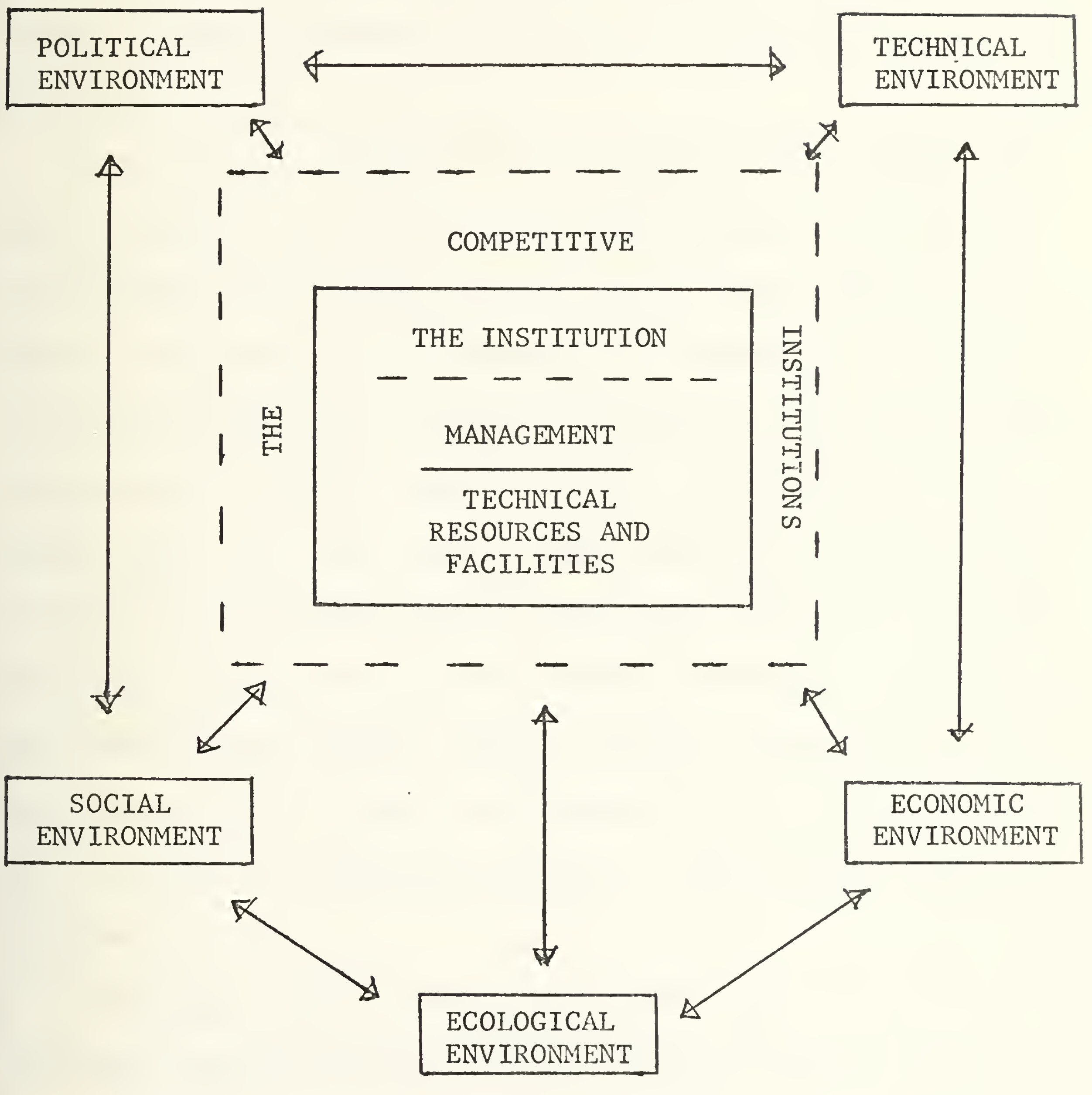


Figure 1: Within each environment are individuals and organizations whose value systems may be changing at the time and perhaps in a vastly different manner than in other parts of the system.

The technological forecaster then must recognize that the parts of this process do not take place in a vacuum but at activities in a very complex social system involving, at times, as many as five major environments. Figure 1 schematically suggests these invironments and the institution's interactions with them.

To be useful, "Technological forecasts do not necessarily need to predict the precise form technology will take in a given application at some specific future date." [Ref. 3]. Rather, the objective of technological forecasting is to acquire a prediction, with some level of confidence, of a technological achievement in a given time frame with a specified level of support [Ref. 9]. The use of a more explicit forecast, based on historical fact and clearly presented, will help to justify proposed program goals and will enhance chances of approval. Any technological forecast makes a basic assumption that the technology needed to make the forecast come true will transfer from discovery to innovation to use, or experience technology transfer.

Technology transfer provides a useful tool to structure thinking around technological forecasting. Figure 2 shows various impact and development levels with an example of the transfer from recognition of semi-conductors to a level of use in Communication systems.

Figure 2

	Technology Transfer level	Example
Impact levels	8. Society.	8. Implication of communication for society.
	7. Social Systems	7. Defense and other national aspects of communications.
	6. Environments.	6. Communication sector for industry.
	5. Applications.	5. Market for communication systems.
Development levels	4. Functional Technological systems.	4. Solid-state communication systems and functional sub systems.
	3. Elementary technology.	3. Solid-state technology, integrated circuit technology.
	2. Technological resources.	2. Diffusion techniques, planar techniques.
	1. Scientific resources.	1. Recognition of the natural phenomenon of semi-conduction.
Decision of progress.		"Majority" and minority carrier concept.

Figure 2: Technology transfer levels with an example of transfer of semi-conductors to communication system.

Note that, levels 1 through 4 are simply predictions of technology moving through different stages of technical achievement, and level 5 implies a prediction about adoption of the technology.

Technological forecasting might be started at or focused on any one of several levels of emergence and impact, and should not be unthinkingly applied to other levels [Ref. 37].

Application at levels 5, 6, 7, 8 involve much more than technology; at these levels a multitude of socio-economic and cultural factors influence technological transfer and forecasting [Ref. 27].

Technology transfer can now be seen as taking place in a horizontal as well as in a vertical direction. Vertical transfer leads from fundamental science to technology, then to systems (products, processes, etc.) and their impacts on different levels. Horizontal transfer passes from one user to another at the same level, represents for example: empirical postulation of a scientific theory might take place at level 1, fructification of other fundamental technological research at level 2, merger of discrete technologies at level 3, diffusion of existent technology at level 4, demand for auxilliary or support systems at level 5, invasion of other industrial sectors at level 6, technical aid programme for developing countries at level 7, and ethical constraints on social goals at level 8. [Ref. 20]. Forecasting can thus range from very broad predictions of the effects of technology on segments of the economy or society as a whole, to relatively narrow, detailed studies of technological progress in only one technical area, and finally to the initial understanding

of how a basic phenomenon, can be applied to the solution of a practical problem. Cetron believes that technological forecasts are realistic estimates by technologically knowledgeable persons, of the rate, direction, and extent to which a particular technology or group of technologies will develop in a specific period of time [Ref. 9]. The purpose of the forecast is to separate clearly the more likely technical states from the less likely.

The above statement can serve as a good definition of technological forecasting. Perhaps a more precise definition is: "Technological forecasting is the probabilistic assessment of future technology transfer." [Ref. 20].

It should be noted here, that forecasting can be improved if the processes by which technology emerges into social use become better understood and applied. By studying the sources of technical concepts and those factors that support or inhibit their progress as they develop and diffuse throughout society, forecasters will have a better idea of what things to measure, estimate, or consider [Ref. 27].

Cetron [Ref. 9] explains that forecasting at levels 1 through 4 is conventionally referred to as "State-of-the-art" projection, or exploratory forecasting. He refers to forecasting at levels 5 through 8 as normative forecasting.

C. EXPLORATORY AND NORMATIVE TECHNOLOGICAL FORECASTING

Technological forecasting is essentially concerned with the forecasting of technological change. If by technological change one understands the development of the applied sciences and their industrial exploitation, then forecasting will primarily be concerned with the capabilities provided by the changing state of the art, and its influence on the materials and techniques employed in industrial production.

It is the complexity of the interactions between changing technology and the complex and changing environment which present technological forecasting with its most formidable difficulties. Analysis may help to break a question down into its component parts and allow a clearer base for judgment. It may also facilitate the use of quantitative as well as qualitative information. In any case, because of the uncertainties involved, the interpretation and very often the basis for any technological forecasting could remain a matter of judgment.

There are two distinct approaches to forecast procedure. These approaches are fundamentally different, one being opportunity oriented, and the other goal or objective oriented.

1. Exploratory Technological Forecasting

"The opportunity-oriented approach is most useful to the industrial corporation that has essentially selected its product line and is concerned with maintaining a competitive

position within that line. It is also the approach that is most likely to be of use to the military planner." [Ref. 28]. This type of forecasting, however, is more concerned with defining the goals and identifying the opportunities.

There are two distinct ways of doing this: the first is to generate new technological information, and the second is to order and structure any given information [Ref. 29]. In either way, the term "exploratory technological forecasting" would be of use to note any attempt to predict the course of technological change. The subject of such a forecast may be the course of development in a particular applied science, or the rate and extent of the diffusion of a particular new or improved technology in industrial practice during a given number of years [Ref. 30].

The forecast presentation will, to a large extent, be governed by the methodology used to project the field of technology. The methods used to forecast the future state-of-the-art are generally categorized as techniques, (see Appendix B). Most of the exploratory forecasts are based on informed opinion or intuitive judgment.

An excellent example of a typical opportunity oriented or exploratory technological forecast is illustrated by Jantsch at all levels of technology transfer. Figure 3 represents exploratory technological forecasting with an example at different technology transfer levels.

Figure 3

Level of Technology transfer	Item to be Forecast
8. Society	Impact on society
7. Social systems	Impact on national economy, defense, health program.
6. Environments	Consequences for structure of industry, leadership of innovating companies.
5. Applications	Technological, economic and social acceptance, measure of success.
4. Functional technological systems	Description of system and detailed performance characteristics, development of time and effort.
3. Elementary technology	Functional capabilities, technological parameters.
2. Technological resources.	Basic technological potential.
1. Scientific resources	Trends in scientific principles and theories, unapplied knowledge, applicability to technological progress.

Figure 3: Example of technological forecasts of different technology transfer levels.

"Explorative forecasts may be made for any technological parameter for which a data base of past performance exists. However, the forecaster usually has at least an intuitive feel that worthwhile goals exist for the further development of the technology he is forecasting." [Ref. 2]. Additionally it may modify the trend on the basis of knowledge concerning the value of the predicted progress. This approach to technological forecasting has limitations, causing resulting forecasts to be subject to change caused by:

- Unpredictable interactions
- Unprecedented demands
- Major discoveries
- Inadequate data
- Cost of system introduction
- They are not used [Ref. 31].

2. Normative Technological Forecasting

When the forecast is "needs oriented" it is termed "Normative."

"In the normative forecast, goals, needs, objectives or desires are specified and the forecast works backward to the present to see what capabilities now exist or could be extrapolated to meet future goals. In some cases the goal may even force technology." [Ref. 9].

Jantsch has stated that, typical basic attitudes that lead normative forecasting include the following:

- Recognition of responsibility toward society or the nation.
- Recognition of economic potentials.
- Recognition of an ultimate technological potential.
- Awareness of constraints, for example in natural resources, company resources, etc.
- Hedging against threats. [Ref. 20].

He is one of the very strong advocaters of the normative approaches, and has called this method "Mission-oriented" forecasting.

Normative technological forecasting first assesses future goals, threats, or missions, then considers the impact of the projected technology, and finally works backward to the present.

According to Cetron, "In this conceptual scheme, exploratory forecasting becomes an input to normative forecasting, which in turn becomes the input to a technological plan that can commit resources to the implementation of the desired technology transfer, and thereby "Invent the future." [Ref 9].

Normative technological forecasting tackles the following characteristic tasks, as illustrated by an example from space technology in Figure 4. [Ref. 20].

Figure 4

Level of Technology Transfer	To be Forecast
8. Society	Social goals
7. Social systems	National objectives
6. Environments	Missions
5. Applications	Tasks
4. Functional Technological systems	Relevance of systems to tasks, technological feasibility, cost/effectiveness.
3. Elementary technology	Relevance of feasibility, development gaps, etc.
2. Technological resources	Technological potentials and limitations, required fundamental technological research.
1. Scientific resources	Absolute (natural) potentials and limitations, required fundamental scientific research.

Figure 4: Normative forecast tasks at various technology transfer levels.

Jantsch states that normative technological forecasting is meaningful only if the levels to which it is applied are characterized by constraints such as natural or artificial forces, or by consensus, such as an agreed set of values or ethical directives [Ref. 20]. In concurring, Cetron adds that the effectiveness of any normative approach depends upon:

a. Meaningfulness of its treatment of goals.

b. Correctness of its assumed relationships between allocated resources and generated technology.

c. The adequacy of its balancing of the resources-to-technology considerations against the worth of goal fulfillment.

d. The implementability of the method, including the ability to acquire reasonable inputs at reasonable costs as well as the ability to persuade organizational decision-makers to use the generated outputs.

e. Cost of inputs.

f. Dubious accuracy of the estimates.

g. Inflexibility of methods.

h. Probable limited impact on managerial decisions. [Ref. 31].

The following concludes the discussion of the Normative and exploratory technological forecasting approaches.

"Of prime importance is that these two forecasting approaches are not competitive, but are complementary. Therefore neither is "best," and if the question is asked, "which group of forecasting techniques should be used? The answer is "both" [Ref. 2].

Knowledge and use of both exploratory and normative methods are essential for effective technological forecasting. "Visibility and discipline can be gained through the use of exploratory forecasting to define what may be possible. Vision and inspiration can be gained through the use of normative forecasting to define what is useful and desirable." [Ref. 2].

A complete technological forecasting exercise should include an iterative process between exploratory and normative forecasting. It should be noted, however, that the process should not match rigid sets of technological opportunities with equally rigid sets of objectives. Rather, it should order them in such a way that the right key fits the right key hole, and constitute a feedback cycle in which both opportunities and objectives are treated as adaptive inputs [Ref. 32]. Figure 5 represents exploratory and normative technological forecasting which relate to the polarity between action and reaction. It is important to note that the interaction of exploratory and normative forecasting be stated correctly. In Figure 5 the forecast of a particular technology transfer, as represented by the vectors of exploratory and normative forecasting in the technology transfer space, has to be made within an additional time frame.

It is evident that the search for new and more suitable opportunities goes hand in hand with the adaption of goals to technological feasibilities and higher probabilities.

Figure 5

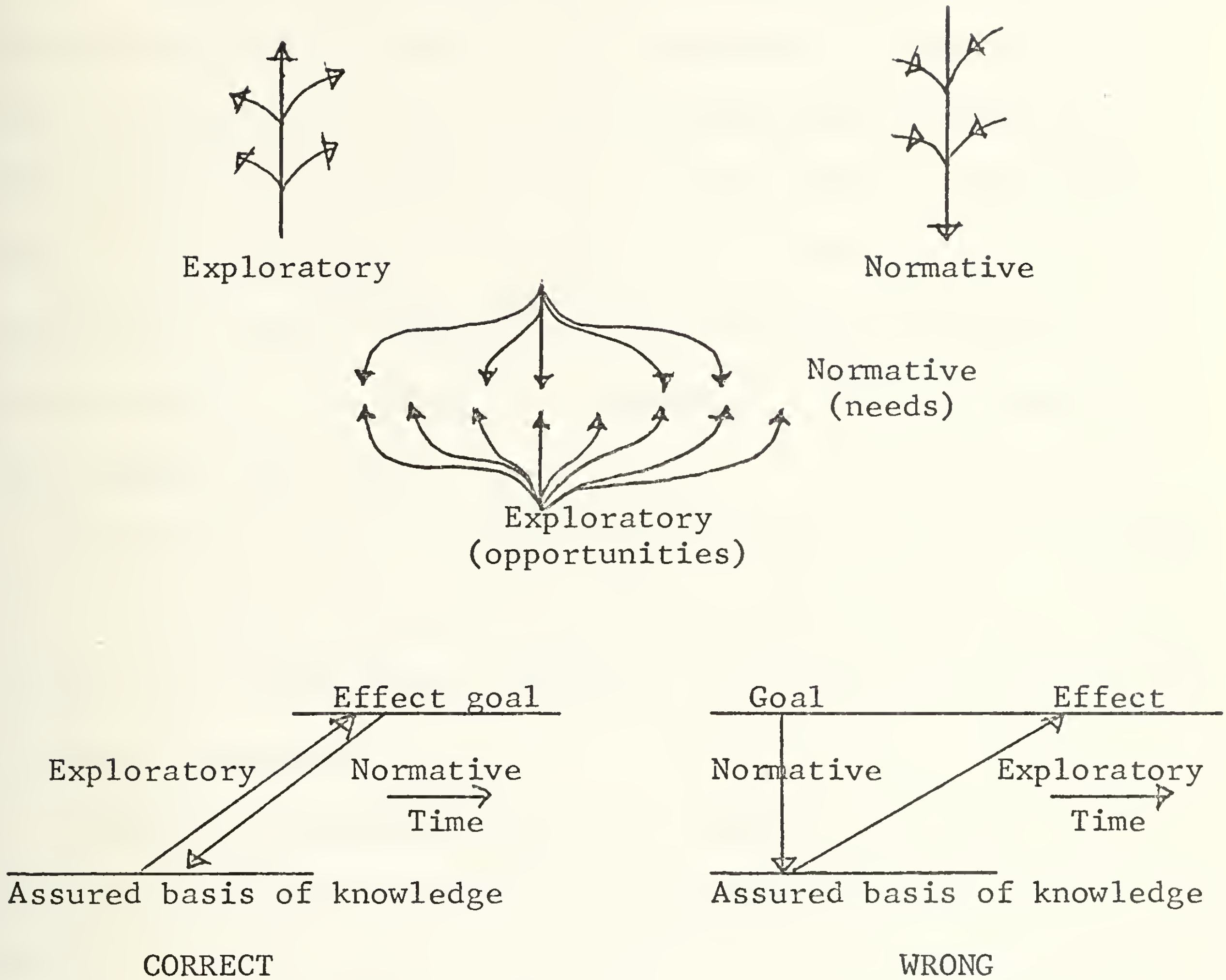


Figure 5: The interaction between Exploratory and Normative forecasts, within an additional time-frame.

According to Jantsch, the most difficult problem in technological forecasting today is the placing of normative forecasting in the correct time-frame. The above figure shows how a correct forecast includes a correct interaction between the two elements of Exploratory and Normative forecast.

D. METHODOLOGIES OF TECHNOLOGICAL FORECASTING

Technological forecasting methods range from naive intuitive approaches to ultra-sophisticated procedures. Extensive treatment of technological forecasting methodologies (according to many experts) can be found in M. J. Cetron [Ref. 9 and 31] and Jantsch [Ref. 20] and J. R. Bright (Ed.), Technological Forecasting for Industry and Government (Englewood Cliffs, N. J. Prentice-Hall, Inc., 1968), (no reference in this research) and also Bright [Ref. 26].

The methods used in technological forecasting can be refined to, (1) Intuitive extrapolative, (2) Correlative, and (3) Logical sequence or network type techniques. Following are explanations of these techniques.

Intuitive forecasting; the most common method employed, can be done individually by genius forecasting or by consensus. "Delphi," the best known method under this classification, has been described in appendix B, attached to this research.

According to Daniel D. Roman, a plethora of methods exist which are essentially variations of "Pert," these include: relevance trees, graphic models, decision trees, and systems analysis, planning-programming-budgeting systems (PPBS), and Mission network. All use "Network" construction to derive technological forecasts [Ref. 33]. He states that, "If numbers are any criteria, it would seem that after some

variation of delphi the network technique is the most popular avenue to technological forecasting. Networks help in identifying and establishing a logical pattern from an existing point to an anticipated goal. An intuitive method, regardless of individual technological perception, might ignore or minimize a significant obstacle to technological attainment." [Ref. 33].

At this point it is necessary to note that, to some extent, the following three points depend on each other and are characteristic of all existing techniques for technological forecasting.

1. "They have been developed for a 'Man-technique dialogue' and are very sensitive to man's knowledge and his capacity for imaginative thinking, technical and value judgment, and synthesis.
2. "They are partial techniques which cover only a fraction of a complete technological forecasting process; their combination may result in more highly, but not yet fully integrated techniques (on the basis of today's state of the art).
3. "They are auxilliary aids to decision-making, which normally has to be based on broader information than can be provided by these techniques." [Ref. 20].

Appendix B illustrates various methodologies for technology forecasting schematically, with detailed explanation of the Delphi technique.

V. THE INSTITUTIONAL IMPLICATIONS OF THE USE OF TECHNOLOGICAL FORECASTING IN PLANNING

A. INTRODUCTION AND SCOPE

In a well-managed company, management sets out to invest its resources to produce the maximum short- and long-term gain. In general, experience has shown that investment in R & D results in the new products that are essential for a company's survival and growth. According to B. V. Dean, most companies have no choice but to continue to invest in R & D [Ref. 40].

Total R & D expenditure in the U.S.A. is expected to exceed $35 billion in 1975. This represents an increase of about 8 to 10 percent over 1974, which the national science foundation estimates at about $32.1 billion. These figures are from forecasts made recently by Battelle and by Research/Development magazine in its January 1975 issue. These reports indicate that, Government and Industry have become more interested in R & D projects.

Dr. Dean's surveys show: "only 45 percent of company's R & D projects contribute to the company's profitability." [Ref. 40]. To increase this rate, the R & D managers should see technology as a three legged stool with planning and control, technological change, and technological forecasting comprising the three legs. If a company has a long-range planning program,

it will know what it wants to achieve, and can, therefore, begin to cost out the R & D expenditure needed to meet objectives.

Dr. Dean states that, although companies are increasingly using quantitative methods for project selection, there are evidences that, formal, quantitative methods are not widely used. "The lack of use of these methods is based on shortcomings of the models themselves, many of which omit factors that are critical in project selection decision making. Some of these factors are:

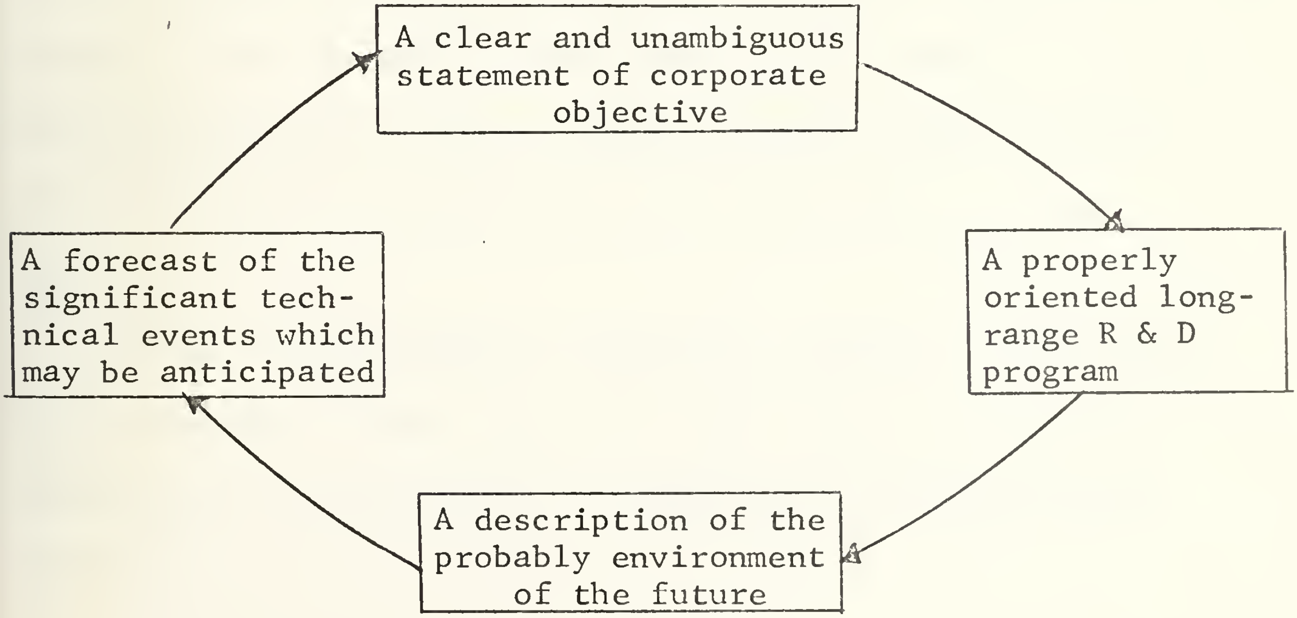
1. Adequate treatment of risk and uncertainty.
2. The need for multiple criteria.
3. The role of experience and intuition in such decision making." [Ref. 40].

Technological forecasting is thus important in the development of R & D planning especially among the more technically-oriented companies.

It was mentioned in Chapter Three, that, planning and decision-making in a basic sense, and in a modern sense is no longer point-to-point planning. Also, forecasting is no more a spelling out of supposedly predetermined end-points, which, as we know today, do not exist a-priori. Modern planning increasingly assumes the character of a process that needs technological forecasting to map out technological options and

interactions, and at the same time, enhance the quality of forecasting by plotting alternative paths to link the future to present action. R & D planning, as any dynamic planning, follows this rule. The primary present use of technological forecasting is in the area of R & D project selection and budget allocation in technically-oriented companies. This idea is presented by Dr. North, and shown in Figure 6 "The chicken and egg proposition" to locate the technological forecasting in the planning cycle [Ref. 41].

Figure 6
The R & D Planning Cycle
(or which came first?)



According to Erick Jantsch, a noted writer in the technological forecasting field, "Technological forecasting not related to action in the present is meaningless." ---and "the more planning advances in the continuous search and modification direction, the more technological forecasting will become an integral part of planning." [Ref. 13]. Quinn and Steiner both have stated, that in many respects technological forecasting can be considered as being quite similar to market or economic forecasts [Ref. 3 and 19]. The value of technological forecasting for management is like any other forecast. In many circumstances, competent persons can usefully predict "expected" future technological capabilities and analyze the probability and implications of variations around them. Quinn states that such forecasts can help to identify and assess opportunities and threats in the company's environment so that managers can act more effectively to improve their company's future position. Such should be the objective of any forecasting activity. [Ref. 3].

Steiner has proposed 10 statements relating to the subject of forecasting. Among these, the more important guidelines and conclusions for improving R & D management planning are the following:

1. Advancing technology makes it imperative that every business become more concerned about planning and its

R & D program at a higher level than it did in the past. This does not mean, of course, that every business must allocate dollars to R & D, but it means that all should at least be aware of it more than in the past.

2. The best basis for R & D planning is an overall comprehensive planning framework.
3. Technological forecasting is feasible within limits and there are many different methods available for companies that need to make such forecasts [Ref. 19].

In accordance with these guidelines, this chapter will trace the emergence of technological forecasting as a factor in the R & D planning and decision-making process.

B. MANAGEMENT APPROACHES TO CONTEMPLATING TECHNOLOGICAL FORECASTING

In an age of accelerating technological change, corporate management can view technological forecasting in a number of significantly different ways. The decision on whether or not to invest in such forecasting procedures, however, must be determined by the wider decision on whether or not to engage in technological research itself. This is not an easy decision for the medium and small size company. Most would respond with an automatic negative. Nevertheless, the alternative, whether

research or development intensive, does exist. The forecasting will frequently provide pay-off [Ref. 42].

The critical mass of funding required by both research, and development intensive companies is frequently so high that the expenditure is prohibitive. An approach used by companies to attain economies of scale in research and technological forecasting is through jointly sponsored trade research establishments.

Ansoff and Stewart have suggested that there are in fact four policy approaches facing most firms which find themselves in an industry based on changing technology.

a - First to market, based on strong R & D, technical leadership and risk taking.

b - Follow the leader, based on strong development resources and an ability to react quickly when the market starts its growth phase.

c - Application engineering, based on product modification to fit the needs of particular customer segments in mature markets.

d - Me-too, based on superior manufacturing efficiency or cost control [Ref. 43].

Each of these policy approaches, of course, has strong and weak points under different conditions, whichever strategy is adopted requires an effective process of communication within

the company functional framework. Of course it will not always be effective for the pattern of communication to operate in a linked form. At times marketing may well need to deal directly with R & D and, R & D may sometimes wish to deal directly with customers [Ref. 42].

In their study of the management of innovation, Burns and Stalker have shown that only certain styles of organization can adequately administer to the rapid adjustments of organizational activity inherent in rapidly changing technology like electronics [Ref. 44]. They stated that the organic system is able to adjust and absorb new roles in a way that the mechanistic system could not. In this field much has been written, and much research has been undertaken, demonstrating the vital importance of organizational flexibility if technological advances are to be successfully commercialized. According to Morton, this is where you need management people, the creation and renewal of the purpose, content, and structure of organizations are the specialized job of the managers. He also stated that creative, specialized people must be present, and coupled together, not just in research and development, but also in manufacturing marketing, sales, and services. Otherwise, total innovation does not come about [Ref. 8].

Patterns of diffusion of new technology have a critical significance to which attention should also be given. Wills

states "For many manufacturers with heavy capital investment in previous technologies, the critical question is the speed with which the market for such a product of technology will develop, as well, of course, as the dimensions of its eventual size." . . . . "For the follow-the-leader strategy, careful and continuous monitoring of innovation will in many fields be sufficient indication of a need for concentrated development work to produce a satisfactory competitive product, with sufficient differentiation and even superiority based on exhaustive analysis of market response to the innovator." [Ref. 42].

There are three major techniques currently used for ensuring that a continuous evaluation of competitive activity is sustained. The life cycle model, technological mapping, and strategic analysis. These are explained by Quinn as follows.

The life cycle model has been used to ensure that marketing and R & D investment costs are recovered over a relevant period before product sales are undermined by substitution. . . . Technological mapping can be sketched from the basic work already carried out for the technological forecast. . . . Strategic analysis is a logical extension of technological mapping. Valuable indications can often be gained from announcements of mergers and acquisition, or from new product introductions which indicate a new direction of activity [Ref. 3].

The above quotations indicate the reasons behind management activities to contemplate technological forecasting or not to invest in technological forecasting procedures. It is important to note here, that not all companies should contemplate technological forecasting as yet one more tool of management technology which must be added to their management services departments. Technological forecasting however has a significance for all who do not use it as well as for those who do [Ref. 42].

For management of enterprises where technological innovation is stressed, techniques described by Quinn offer significant promise of a more effective system of planned and controlled R & D, with a substantial reduction in acts of faith in the pure research laboratories.

This is illustrated by a quotation from Wills. "Perhaps the most hopeful aspect of technological forecasting, however, is that in the hands of companies and governments of which one approves, it can at last afford society the opportunity to decide what sort of future it wants. The forecast well prepared poses the alternatives for debate, before the resources for achieving any particular one are committed irrevocably." [Ref. 42].

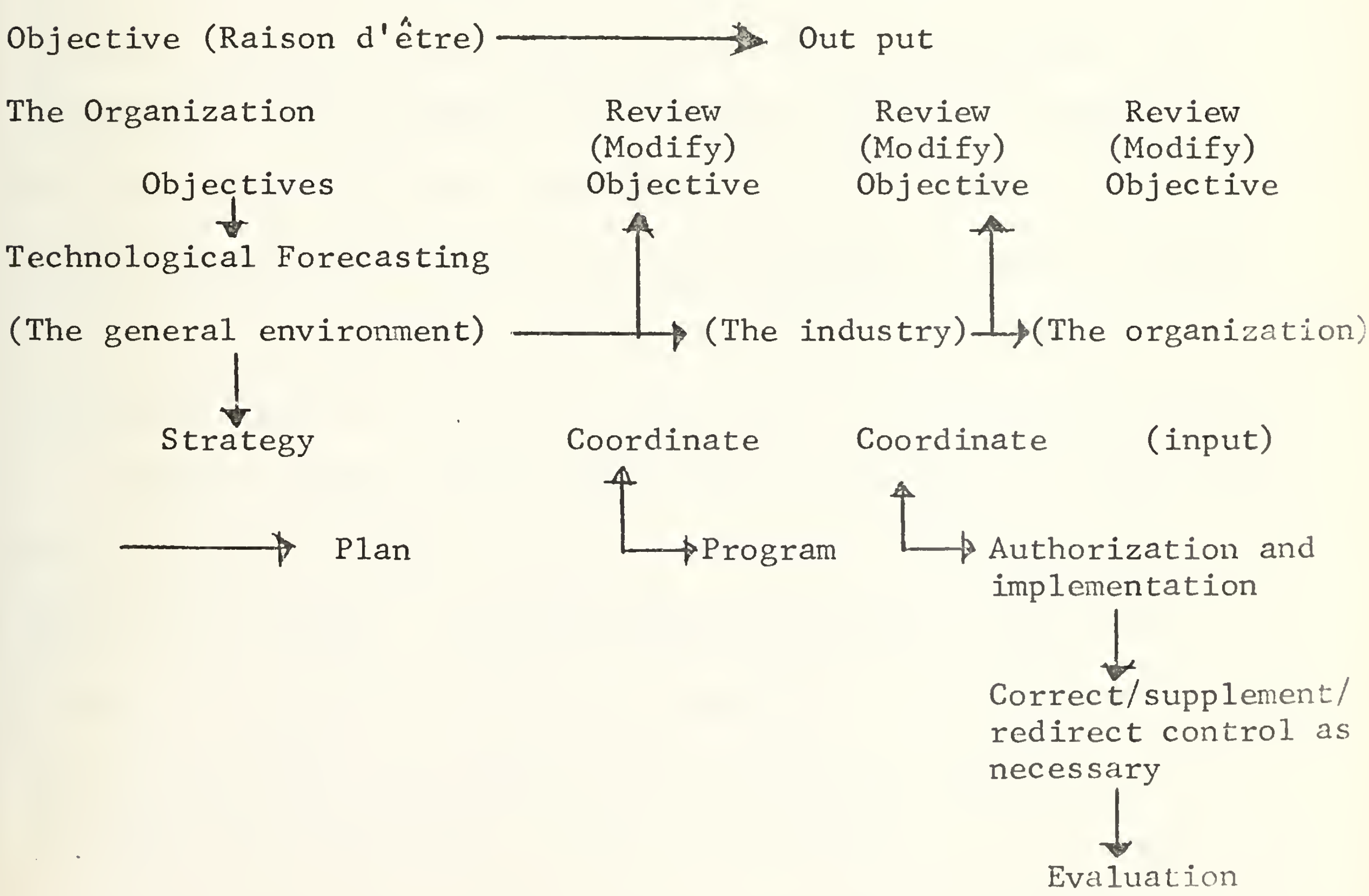
The discussion of management approaches is concluded with some organizational comments by Daniel D. Roman. He states that there are several factors management must consider before commiting itself to technological forecasting. It must look at the

type of operation in which it is involved. Is the organization in a technologically sensitive environment? Is the organization a leader or follower in its operational environment? Are operations large enough to justify commitment to a technological forecasting activity? [Ref. 33].

Figure 7 shows how technological forecasting might be integrated into the management process.

Figure 7

Technological Forecasting in the Decision Process



C. THE SCOPE OF LONG-RANGE PLANNING

According to many well known writers in the technological forecasting field, it is useful to distinguish between perceptual levels of action, and to look at the possibility of rationalization by applying a planning process, or an advanced scheme of corporate planning. Distinguishing between these levels of action is necessary for the development of realistic strategic plans in areas marked by rapid technological change [Ref. 32].

Before discussing levels of planning, it is important to make clear what planning is, and what it is not. Peter F. Drucker, one of the well known writers in the management area states that, three things in particular, which are commonly believed to be planning, emphatically are not. First it is not forecasting, a plan is not a precise statement of what is going to happen, but is rather a statement of what looks like a reasonable course of action in the light of available information.

Second, it does not deal with future decision: It deals with the futurity of present decisions. That is, decisions exist only in the present. The question that faces the long-range planner is not what we should do tomorrow. It is what do we have to do today to be ready for an uncertain tomorrow? The question is not what will happen in the future. It is: what futurity do we have to factor into our present thinking and

doing, what time-spans do we have to consider, and how do we converge then to a simultaneous decision in the present?

Finally, the most common misconception of all: long-range planning is not an attempt to eliminate risk [Ref. 45].

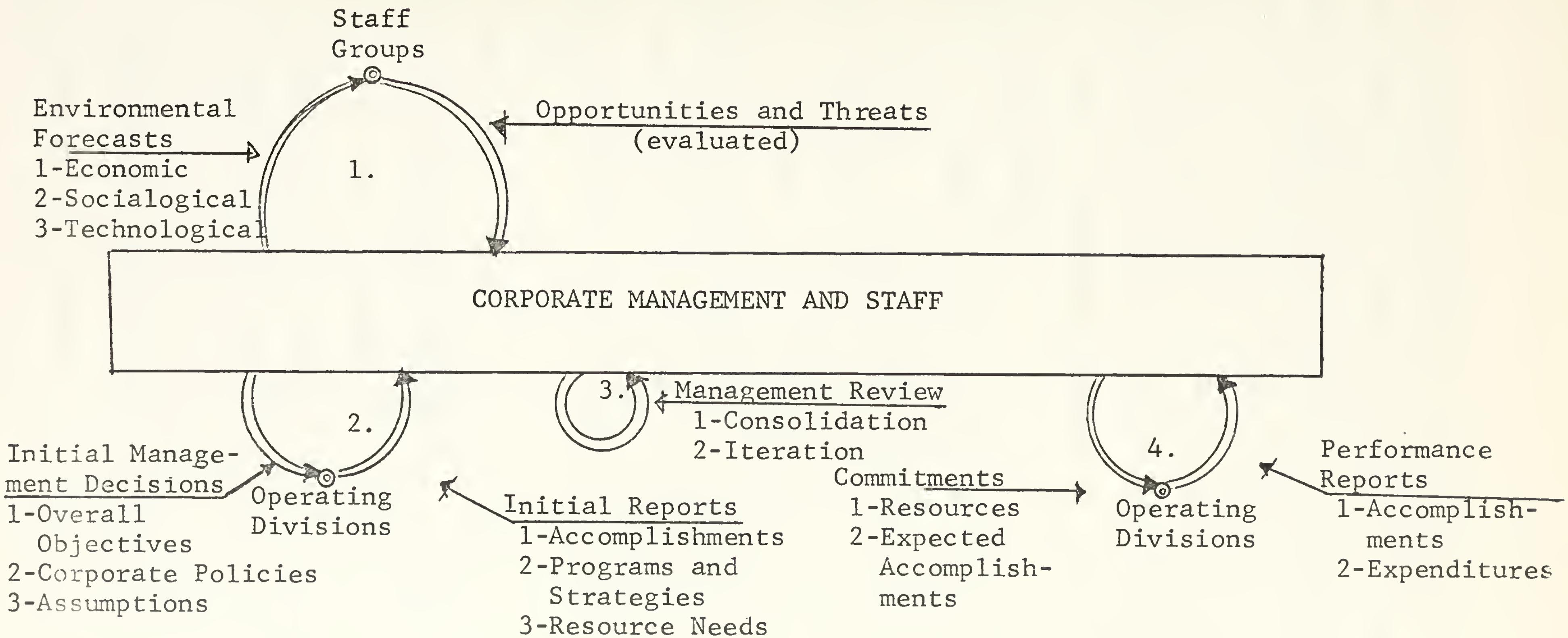
Drucker points out that not only is risk inherent in economic activity, it is essential to profitable economic activity. The purpose then of planning, is to assure that the risks taken are the right risks.

Now to turn from what planning is not to what planning is. According to Quinn, "Planning is the process of making decisions which will tend to optimize the organizations future position despite random or organized changes in its future environment." [Ref. 18]. He states also that, forecasting is not planning. Forecasting predicts the probable effects of interactions between these futures and various decisions the organization may make. Figure 8 describes the critical steps in long-range planning.

In looking at levels of action and the possibility of rationalization of the context of technological change and its effect on technological forecasting, Jantsch states that, these levels of action in the long-range planning are: "Attitude," "policy-making," "Strategic decision-making," and "tactical decision-making." The form, in this order, a logical sequence leading to the initiation and implementation of action

Figure 8

Critical Steps in Long-Range Planning



significantly growing recognition of the necessity to "shape the future" arose with a change in attitude that was not planned but emerged in response to a change in environment [Ref. 13].

This view of thinking is strongly advocated by Dunckel and Wilson when they state that, the political and social dimensions of forecasting must be added to the more traditional technical and economic ones if business planning is to be effective in the seventies [Ref. 46].

Planning, as viewed in this study, is essentially "future-creative" planning. In the version formulated by Ozbekhan, it lies between the three levels of normative planning (the ought), strategic planning (the can), and the operational planning (the will). Motivation, based on values, is not part of this rational sequence, although it acts as an energizing force. Values cannot be planned, but attitudes, policies, and decisions can [Ref. 13].

Ayres elaborates: In real life, inventing the future is the province of planning and programming, although a vital prior role may be granted to the process of recognizing or formulating long-range needs or goals at various levels of social, political, or economic organization [Ref. 34]. He states that, it is sometimes useful to visualize a hierarchy of imperatives. Analogous distinctions between levels of analysis can then be made for any type of organization or structured collection of

functions and activities. In every case, needs, purposes, aims, goals, objectives, missions, and tasks are listed in decreasing order of generality or universality, and increasing order of specificity. Figure 9 shows such a hierarchy.

Figure 9

A Hierarchy of Imperatives

Level	Essential Purpose
Biological (needs)	Essential purpose to survive and reproduce the species.
Individual (needs, wants)	To be happy, to be good (or avoid sin), to achieve personal status or power, etc.
National (U.S.A.) (Historical purposes)	To perfect democracy and "freedom" to promote social justice and equal opportunity, to protect citizens, etc.
Defense Department (goals/postures)	To deter attack and to fight wars.
NAVY (Objectives, missions/ strategies)	To protect sea lanes (transoceanic shipping routes) and control the oceans; to fight hostile naval forces, United States land and air forces.
Carrier task group mission, task/tactics	To carry out operations in support of the above.

This hierarchial representation provided a natural framework for distinguishing several levels of planning in government or industry.

Understanding of both the natural framework and the attitudinal way of thinking is important for the assessment of the role of technological forecasting. Any specific environment gives birth to a new attitude. The matured attitude, then, seems to become a prerequisite for the recognition of a new environment [Ref. 13]. Figure 10 shows the American attitudes towards R & D, and the emergence in a non-controlled way of responses to changing environments. According to Jantsch a considerable time-lag exists between first emergence and large-scale effect of a new attitude: Strategic function-oriented planning for R & D is only now gaining ground outside the defense and space areas [Ref. 13]. It is ironic that very little is known today about the development of attitudes. This is a gap which must be narrowed before we can hope to plan for attitude changes.

Figure 10

American Attitudes Towards R & D

Time of Initiation	(Anticipated) Environmental Conditions	Emerging Attitude Towards R & D
1944	Post-war peaceful development	No planning of research; emphasis on cooperative research; small science based industry which would not "plan" but "try out" new products, etc.
Around 1950	Cold war and limited war	Tactical planning acceleration of action through strong normative thinking (crash programs) dynamic attitude.
Late 1950's	Competition for leadership	Strategic long-range planning, becoming increasingly function-oriented; systems analysis as basis for R & D planning.
Late 1960's	Acception of responsibilities on national and global scale in view of dangerously widening "gaps" growing disequilibrium in uncontrolled systems.	Shaping the future recognition of the need for policy-planning.

PLANNING FOR POLICY-MAKING

Policy planning, which is concerned with goals, seldom involves technological considerations in any central way /Ref. 34/. In this context "Jantsch" states that, "ideally, the goal patterns are to be viewed as consistent anticipations (possible futures), i.e. intellectually constructed models of discrete futures, or substantial fractions thereof. Policies are tentatively selected on a comparative basis, but remain subject to continuous modification and refinement, or even exchange." /Ref. 32/. In another article he referred to policy making as the result of normative planning and as being directed toward the search and establishment of new norms that will help define those values which will be more constant with the problematic environment /Ref. 47/.

PLANNING FOR STRATEGIC DECISION-MAKING

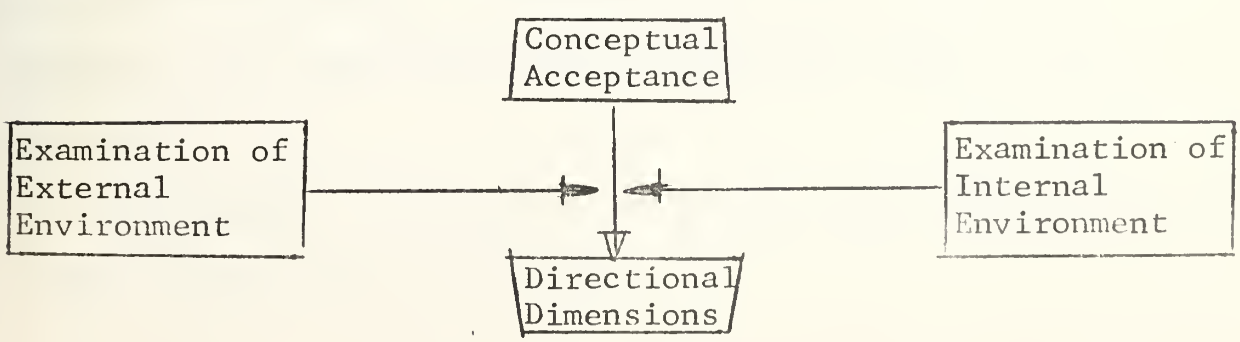
At the strategic decision-making level alternative options for the attainment of specific goals are formed. The "decision agenda," are conceived, followed through to their potential outcomes, and assessed on a comparative basis. Technological planning at this level identifies objectives in strategic terms, e. g., exploitation of resources, or market dominance /Ref. 32/.

Ayres states "Sometimes all of the strategic options involve significant technological development, especially when the goals are related to physical (or biological) problems such as putting a man on the moon, feeding the world's population, cleaning up polluted rivers, or developing a defence against ballistic missiles." [Ref. 34].

A strategic planning sequence could be summarized as shown in Figure 11. Killough believes that in an absolute business environment, the phase of strategic planning calls for the following: (1) the concept to be understood, (2) a need for such planning to be verified, (3) acceptance of the concept by management to be determined, and (4) proper support throughout the organization to be obtained [Ref. 48].

Feasibility trends, in particular trends of technological feasibility, are introduced at this level strictly as potentials which may become norms only in the context of a planned or intuitively selected policy [Ref. 32].

Figure 11
Strategic Planning Sequence



PLANNING FOR TACTICAL DECISION-MAKING

To comprehend industrial planning, it is important to understand the differences between strategic and tactical planning. At one extreme of a spectrum is the strategic planning previously described. At the other end is tactical planning, or the detailed deployment of resources to achieve strategic plans. Tactical planning deals with one particular strategy only, delineating the sequence of action necessary for its implementation. In the framework of technological planning, such a strategy aims at reaching a specific product objective in a technological system [Ref. 32].

Steiner has drawn a line of demarcation between the two extremes to highlight the conceptual distinctions between strategic and tactical planning with no particular order of importance. Some of them are as follows:

LEVEL OF CONDUCT - Strategic planning is conducted at the highest levels of management and relates exclusively to decisions at these levels, which, tactical planning is done at and relates to lower management levels.

SUBJECTIVE VALUES - Strategic planning is more heavily weighted with subjective values of managers than is tactical planning.

UNCERTAINTY - Uncertainty is usually much greater in strategic planning than in tactical.

INFORMATION NEEDS - Strategic planning requires large amounts of information derived from, and relating to, areas of knowledge outside the corporation, while tactical informational needs, in contrast, rely more heavily on internally generated data.

TIME HORIZON - Strategic planning usually covers a long time spectrum although sometimes a short one. The time horizon varies from subject to subject. Tactical planning, in contrast, is of shorter duration and more uniform for all parts of the planning program [Ref. 19]. According to Jantsch, a clear view of technological objectives and the principles and procedures to be used in realizing them, determine the feasibility of operational planning [Ref. 32].

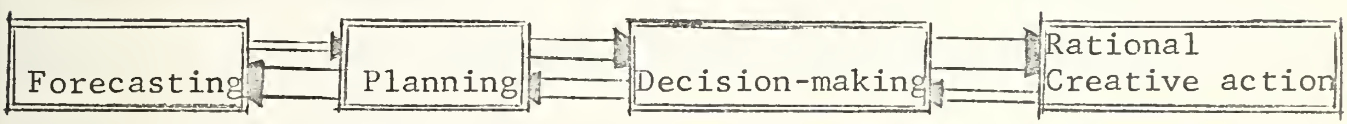
In summary, there are three levels of functional relations between a plan and the environment: a) policy making functions which result in normative planning and are directed toward research and establishment of new norms that will help define those values which will be more constant in respect to the problematic environment. b) goal-setting functions which result in strategic plans wherein various alternative ways of attaining the objectives of the normative plan are reduced to those goals which can be achieved, given the range of feasibilities involved, and the optimum allocation of available resources. c) administrative functions which lead to operational or

tactical planning wherein the strategies that will be implemented are ordered in terms of the priorities, schedules, etc. [Ref. 47]. New (normative) planning unfolds in the feedback interaction between these three levels, while the old planning notion reappears, more or less intact, at the level of the tactical only [Ref. 34].

The process of rational creative action may be conceived as unfolding in the interaction among four activities: forecasting planning, decision-making, and action, as shown in Figure 12.

Figure 12

The Process of Rational Creative Action



Invention	System-Design	Adoption	System Building

Relevance	Motivation	Organization

Forecasting plus planning	=	Planning process
Forecasting plus planning plus decision-making	=	Decision-making process
Forecasting plus planning plus decision-making plus action	=	Process of rational creative action

[Ref. 47]

D. THE ROLE OF TECHNOLOGICAL FORECASTING IN PLANNING PROCESSES

"Technological forecasting is just one of several inputs to the planning process. Its key position and importance is due to the predominant role of technology in social change, a characteristic which is not given a priori but can be assumed to govern or at least strongly influence the dynamics of society for as long a period as we can hope to plan for." [Ref. 13].

Technological forecasting, like corporate planning, originally developed along the lines of a deterministic approach to planning. It adopted the characteristic principles of linearity and sequentiality, to which the rather indiscriminate use of time-series relating to single technical parameters still bears testimony [Ref. 32].

In its primitive form, Jantsch states that technological forecasting provides certain inputs to extrapolative planning but does not interact with other elements of the planning process. In its extreme interpretation it is regarded as an objective source of truth about the future, external to planning and human action. For modern corporate planning, and in particular for technological long-range planning, the purely extrapolative forecasting and planning approach yields nothing but feasibility indications for targets and the pace at which they may be attained. In this context, J. B. Quinn states

"Managers must also imaginatively analyze potential opportunities and threats in the environment to see how they can best develop and exploit the organization's unique capacities and thus maintain its future dynamism. Hence thorough strategic formulation requires: (1) careful forecasts of relevant economic sociological, and technological futures and (2) some means of reflecting these forecasts in major decision processes." [Ref. 18].

A perspective-tree approach to the identification of business threats and opportunities is suggested by Swager [Ref. 4]. Forecasting provides a structured process by which data and arguments can lead to judgments on strategy. The following explanation may serve to describe, in a simplified way, the role of technological forecasting in the four versions of planning previously outlined.

1. Technological Forecasting at the Attitude Level

In planning for attitudes, technological forecasting concentrates on issues such as the role of technology in attaining a new equilibrium to the man-nature relationship; the use of technological options to achieve global stability for mankind; the use of technology, particularly information and communication technology, to attain world unity; and decisions concerning technological development [Ref. 13]. Jantsch states further that, the 1970's will probably see only the beginnings of these far ends of technological forecasting, for which the

required wisdom is certainly not yet available. In this stepwise development, planning changes from discrete "point-to-point" planning to a continuous process of conception, assessment comparative evaluation and tentative choice.

2. Technological Forecasting in Policy Planning

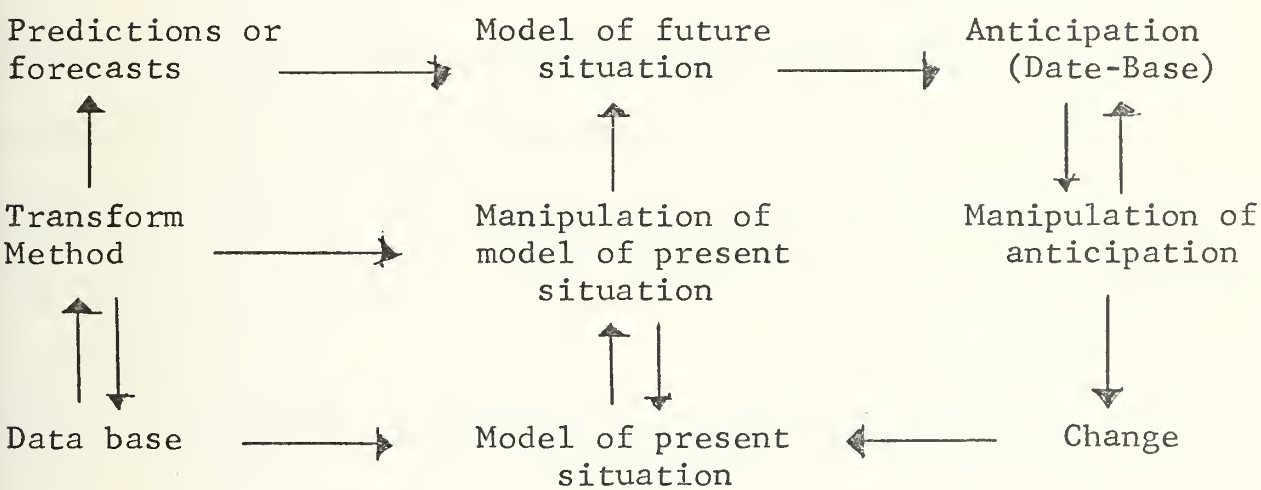
Policy planning, being concerned with goals, seldom involves technological consideration in any central way. Ayres states, technological considerations at the policy level can be handled in a rather simplistic fashion. Frequently the problems themselves are partly, or even largely, created by technology. Examples include the widening economic gap between rich and poor nations, the "brain drain" the domestic threat of unemployment arising from automation, the mounting problems of pollution [Ref. 34].

All of the above contribute to a picture of the future environment within which functional objectives must be chosen by the decision makers. It has been said that, at this level technological forecasting is focused on basic scientific-technological potentialities and limitations, as well as on their conceivable ultimate outcomes in a large system context. The scope becomes a clarification of scientific-technological elements determining the future boundary conditions for corporate development [Ref. 32]. In policy-planning, all levels of perception up to anticipations are characterized by fluctuating

patterns. Planning proceeds in a continuous feedback cycle, for which Ozbekhan proposes the basic scheme shown in Figure 13. The place of technological forecasting as one of the transform methods becomes clear in the following scheme and focuses on the interaction of technology with society [Ref. 49].

Figure 13

The Feedback Scheme Underlying Planning for Anticipation/Planning for Policy Making



3. Technological Forecasting at the Strategic Planning Level

A majority of experts believe that the core of technological forecasting is situated at the strategic-planning level, and it is here that one can recognize and compare alternative technological options (the preparation of the technological decision-agenda). The focus is not on descriptive forecasts

in terms of systems design, but on assessing feasible systems performance in the light of attainable technological capabilities, and on relating technological options to functional missions [Ref. 32].

Of course, strategic planning can be toward diverse objectives, such as: product diversification, better markets, wise use of resources, and various functions, but in the context of technological forecasting, and in the normative sense, functions are translated into R & D problems, often right down to the level of fundamental research. The relevance tree principle fits this type of task extremely well so that it can be successfully applied in many different versions. It may be expected, however, that exploratory technological forecasting will gain in importance, particularly at the strategic planning level [Ref. 13].

4. Technological Forecasting in Tactical-Planning

At this level technological forecasting is aiming at a specific technological solution. Its scope is the probabilitic assessment of future technology transfer, both vertical and horizontal. The forecasts penetrate beyond the design and performance characteristics of a specific technological system to utilization in the context of different applications and services, repercussions in the market system, and implications for social and technological development [Ref. 20].

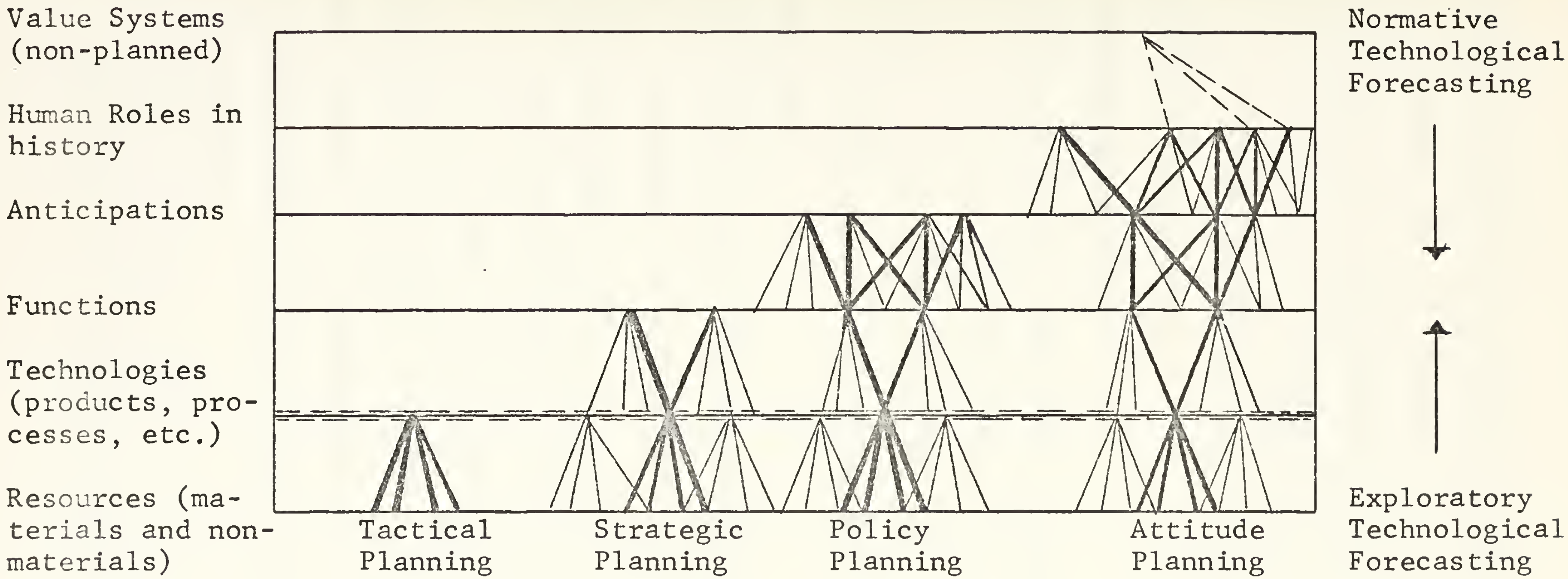
The role of technological forecasting in the planning process, in general, may be summarized in Figure 14. Thin lines indicate the rapidly increasing variety of technological solutions to be considered in planning for functions, anticipations, and human roles. The thick lines indicate that each technology has different outcomes, and that there are different approaches to them. Whereas, in tactical and strategic planning, the starting points for normative technological forecasting are frequently given within the considered time-frame, this does not hold for policy and attitude planning. There, the total spectrum of anticipations and human roles is considered and a relative optimum is sought and continuously modified from feedback information.

E. ORGANIZATIONAL CONSIDERATIONS

A purpose of technological forecasting is the provision of information which will at least partially serve as the basis for planning and decision-making. It is not engaged in for its own sake. If it is not useful for planning and decision-making it is simply wasted effort [Ref. 50]. Success depends in great measure on top management commitment and concern, and involvement and participation by middle management and staff groups. Success measurement is judgmental, we judge our efforts as successful when they clearly identify threats and/or

Figure 14

The Role of Technological Forecasting in the Planning Process



opportunities that had not been seen before, or identify new technical approaches to old problems /Ref. 4/.

Many companies are now experimenting and accumulating experience with various organizational approaches. The following are a few of the more interesting organizational approaches to technological forecasting.

1. Scientific Advisers

Science advisory committees are usually made up of eminent university or government scientists from a wide range of disciplines. The scientists offer advice as to the potential worth and relevance of specific scientific fields.

2. Wild Men

"Wild men" is the name frequently given to the one or two highly imaginative and active individuals management may choose for stimulating really new thoughts on technological potential in their organizations. The wild men are usually extremely talented people, often tempermentally unsuited to fill regular executive posts /Ref. 3/. The wild men may be somewhat disruptive elements in the organization. If they are capable and stimulating enough, however, they can be effective and widely appreciated.

Companies have devised a variety of formal staff organizations to concentrate on technological forecasting, examples are:

3. <u>Staff planning or program evaluation groups</u>

4. <u>Long-range planning groups</u>

5. <u>Opportunity-seeking groups</u>

6. <u>Technological information centers</u> [Ref. 51].

From the viewpoint of organizational location, technological forecasting can be a function or an activity within the function. Figure 15 shows the structure, which is superimposed over the administrative structure, and enforces normative thinking at all hierarchial levels. Figure 16 brings the innovation into sharp focus through a high-level split between the present and the future. This framework for thinking is important for clarifying the position of the technological forecasting function in the corporate structure. It is shown in Figure 17. Several organizational affiliations appear logical, such as: placement in long-range planning, marketing, materials management, or in the research and development group. Technological forecasting can also be elevated to functional status with independent identity [Ref. 33].

Jantsch has stated that, the normal way in which technological forecasting is first incorporated into a complex company structure is as a refinement of a corporate long-range planning function. "The shift towards a vertical, decentralized organization is usually followed by the operation of horizontal, corporate level staff functions which have the task of recognizing and

Figure 15

Innovation emphasis structure (example from an American electronic company). This structure, which is superimposed over the administrative structure, resembles a relevance tree and enforce normative thinking at all hierarchy levels.

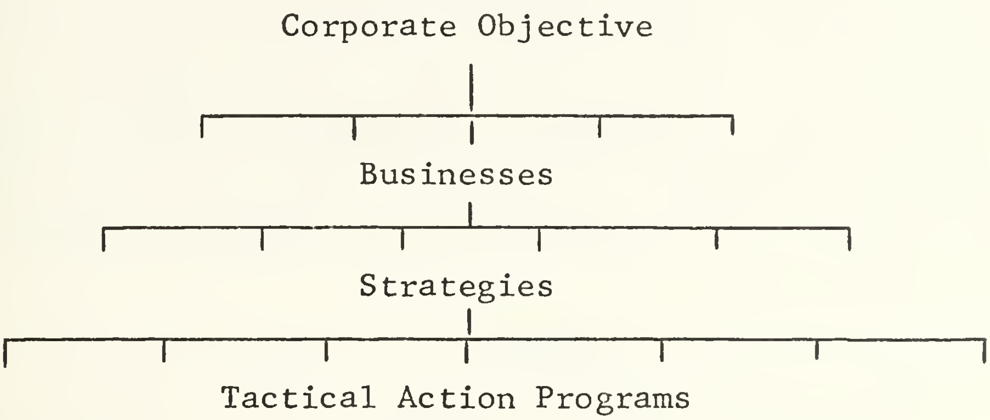


Figure 16

Bringing innovation into sharp focus through a high-level split between the present and the future.

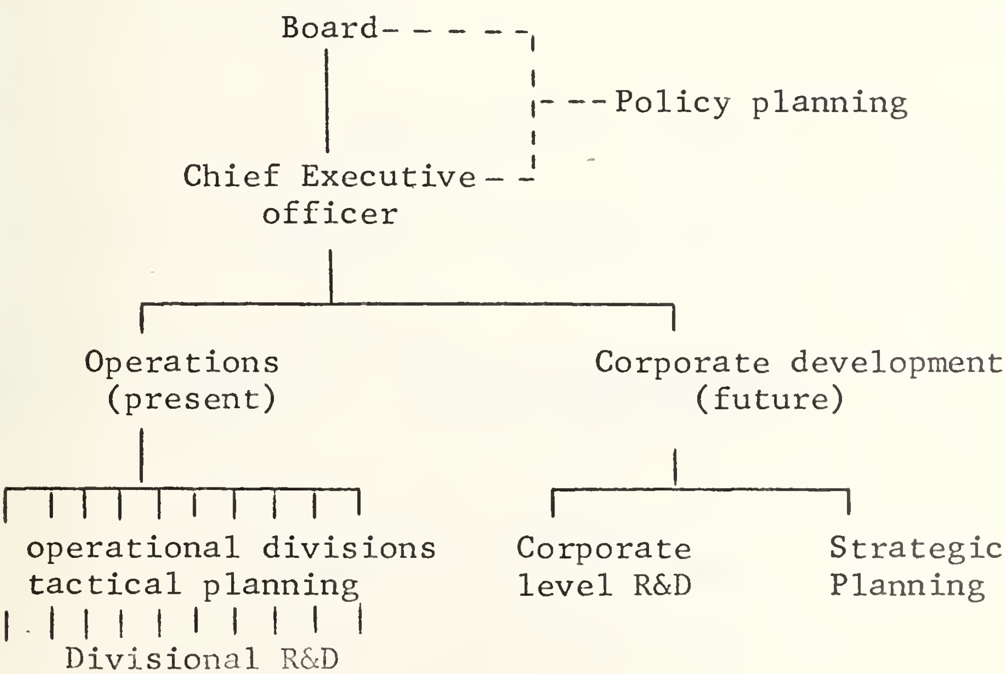
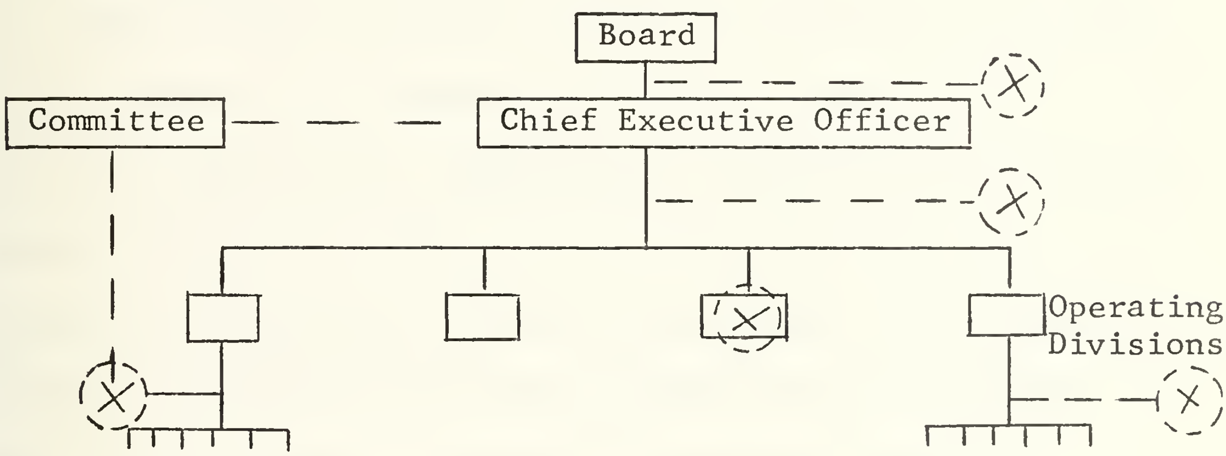


Figure 17

The Position of the Technological Forecasting Function in the Corporate Structure

The Stanford Research Institute distinguishes five positions (marked by a cross) for the "normal" American company. There is a marked trend in favor of a corporate-level staff group and away from management by committees. The Stanford Research Institute's pattern for an "advanced" American company already points toward function-oriented management, at least as far as new products are concerned. In general, technological forecasting is much more closely related to corporate long-range planning than to research and development.



Chief Executive Officer

Future | Production | Marketing | Finance | Admin — Corporate Vice-Presidents

Future:

- Planning Staff
- Research Staff
  - Technical research staff
  - Marketing research staff
- Business Development (Diversification)

analyzing non-routine problems and of proposing solutions. Another frequently encountered organizational form is that of horizontal, corporate-level management committees which are sometimes supported by a small staff." [Ref. 20].

In general, the responsibility for synthesizing technological forecasting at the three different planning levels may be shared as follows.

Technological forecasting for policy-making, at the board level, might be done by special officers reporting to the board (see the example of an American electronic company in Figure 15) or by policy committees. Technological forecasting for strategic decision-making could be done at the corporate level, e.g., by horizontal staff groups, usually incorporating mixed scientific technical and marketing expertise, working for the president or a senior vice president in charge of corporate development. Technological forecasting for tactical decision-making at divisional management level would preferably be done by staff groups [Ref. 32].

There are no clear cut answers or universal solutions to the organizational location of technological forecasting activities. The critical issue in organizing for technological forecasting is not the place in the formal organization structure of the company. Staffing the forecasting activity with high-quality

personnel, and properly integrating forecasts into executive decision processes are of greater importance [Ref. 3].

J. B. Quinn offers four suggestions in this regard.

1. Forecasts should develop the pragmatic insights needed to keep this year's decisions from focusing on esoteric problems of the year 2000. Executives can often understand the need to look 3 to 10 years ahead, but should not waste effort on ultra long-range things of an esoteric nature.

2. Forecasts should place opportunities and threats in an appropriate order of priority.

3. Forecasts should be fitted to the company's regular cycles of executive decision.

4. Promising executives should, whenever possible, be exposed to planning and forecasting activities as a routine part of their training [Ref. 3].

To accomplish the above, many companies try to provide an orientation towards functions and long-range corporate objectives through Matrix-management [Ref. 20]. The general pattern in large companies favors a producer program oriented structure for the operating divisions, and a function, (or discipline), oriented structure for the research division or the corporate-level research laboratory. "The product/function matrix for management thus basically represents a flexible 'task force' approach on the basis of a rigid administrative structure." [Ref.20].

In conclusion, "new organizational forms for forecasting must be designed consistent with the new roles and interrelationships of the social institutions for which the forecasting is performed." [Ref. 52]. Corporations, cities, nations, all are moving toward integrated activities that make them more and more a part of a single system, rather than individual, segregated, autonomous units [Ref. 51]. Thus technological forecasting, as part of planning, in any kind of decision making "depends on decentralized initiative and central synthesis." [Ref. 32]. Figure 18 outlines a possible scheme for the various forecasting stages for the R.D.T. & E. phases of a technological innovation. The decisive role of horizontal, corporate level staff groups in synthesizing technological forecasting is brought out clearly. No fewer than three or four out of the six forecasting stages have the synthesis entrusted to such staff groups.

Figure 18

The organization of technological forecasting within the corporate structure. Each forecasting stage involves the interaction between different levels. The synthesis is always made at the highest level involved.

X - synthesis and inputs   0 - inputs

Board level board officers	X	X					
Corporate level horizontal staff groups	0	X	X	X		X	X
Research laboratories	0	0	0				
Divisional level management (staff groups and divisional groups)		0	0	0	X	0	0
Project engineering groups				0	0	0	

R.D.T. & E. phases: Pre-discovery → Discovery → Creation → Substantiation → Development → Advanced Engineering → Application & service engineering →

Forecasting Objectives							
Environment	Corporate Environment	Technological missions	Technological options	Implication for corporate objectives	Market Implications	Repercussions in market	Feedback
Science and technology	Basic potential and limit	Attainable Technological capabilities	Systems performance	Systems element and development required	Systems design	Production and operational requirements	Feedback

VI. SUMMARY AND CONCLUSIONS

A. TECHNOLOGICAL FORECASTING

The study has shown that there is a clear and fundamental distinction between normative and exploratory technological forecasting. At a technology transfer level, the directions of these forecasts are opposed to each other. Exploratory forecasts emerge from a present assured basis of knowledge and explore future feasibilities and probabilities, while the normative forecast implies the delineation of future goals and their translation into tasks for scientific and technological development.

The most difficult problem in technological forecasting is the placing of normative forecasting in the correct time-frame. Whereas exploratory forecasting encounters little difficulty in conceiving end effects, normative forecasting frequently envisages a set of objectives, requirements, and social goals on the tacit assumption that goals for the present are also representative of goals of the future.

The full potential of technological forecasting is realized only when exploratory and normative components are combined through a feedback cycle into a bi-polar pattern so that needs are matched with opportunities.

The following principal conclusions are given on technological innovation, which is a central element of technological forecasting.

1. The inherent nature of technological innovation generally favors a normative approach, which can be greatly enhanced by the application of technological forecasting with a strong normative component to provide spur and guidance to the technology transfer process.

2. Technological forecasting is the most effective available means of filling the gap between innovation and adoption so as to maintain continuous fast growth.

3. Technological forecasting strongly influences the pattern of vertical technology transfer, especially by greatly improving the systematic exploitation of "commonalities" and by focusing and accelerating the development of complex technological systems.

4. The horizons of application and service engineering will be widened considerably by technological forecasting, and the trend towards greater emphasis on horizontal technology transfer will be strengthened thereby.

5. The forecasting of structural changes in industry and, most important, in industrial patterns, as a result of technological innovation — especially in advanced fields, where technologies are pushed to their ultimate limits, will become

one of the foremost concerns of long-range technological forecasting, possibly at national and international levels.

6. Technological forecasting is not yet a science but an art, and is characterized today by attitudes, not tools. Human judgment is enhanced, and not substituted, by it.

B. TECHNOLOGICAL PLANNING

Technological forecasting is a tool for planning and decision-making, but it is not a plan, a forecast could be a plan if a commitment were made to apply resources to eventuate the forecast. Technological forecasting alone does not determine what will be accomplished in the future in the research and technology areas. This is because the environment is affected by many criteria such as budgeting policies, technological break-through in other areas, and the socio-political environment.

Technological forecasting is one of the varieties of rational analysis available to the decision-maker. It provides information about the future technological environment, including the technologies which compete with them, and the technologies which support or complement them. This can be done only by recognition of the emergence of industry as a planner for society.

If the 1960's can be characterized by the introduction and consolidation of planning for strategic decision-making, the principal task for the 1970's will be the mastery of planning

for policy-making. Technological forecasting has the task of providing the full decision agenda, at the technological level, for the purposes of feedback use in planning. To introduce feedback planning for policy-making, a forward looking institution will be required to coordinate alternative strategic inputs.

The following conclusions have been drawn regarding technological forecasting and technological planning, in terms of merging.

1. Technological forecasting and planning exhibit a marked trend towards fuller integration. This may result in the eventual disappearance of technological forecasting as a distinguishable discipline in the 1970's.

2. The trend towards integration will favor a change from product-oriented towards function-oriented planning.

3. The normative character of planning is enhanced by adapting it to the hierarchic relevance concept which forms the basis of normative technological forecasting. Normative criteria are then introduced at the top only, at the level of the corporate objective. It may embrace supreme social goals and may link economic and military planning to the requirements of society.

4. The quantification of planning in the military, economic and social areas is likely to find a common measure in monetary values. Planning may become more homogeneous through a uniform cost/effectiveness approach in all three areas, greatly facilitating the integration of technological forecasts over a multitude of technology transfer levels and areas.

APPENDIX A

THE BROAD MEANING OF THE BASIC TERMS FREQUENTLY USED IN THIS RESEARCH

The following is intended to explain the meaning of terms used in this research.

DIFFUSION

The evolutionary process of replacement of an old technology by a newer one for solving similar problems or accomplishing similar objectives [Ref. 34].

EXPLORATORY FORECAST

A forecast in which hypothetical future consequences of existing trends are exhibited from the standpoint of a neutral observer or nonparticipant. Exploratory technological forecasting seeks to project technological parameters and/or functional capabilities into the future by starting from a base of accumulated knowledge in relevant areas [Ref. 34 and 2].

FORECAST

A reasonably definite statement about the future, usually qualified in the sense of being contingent on an unchanging or slowly changing environment. "The future" referred to in this notion includes situations, events, attitudes, etc. [Ref. 20 and 34].

INNOVATION

The introduction or application of a new idea or invention; change in the existing order [Ref. 34].

INVENTION

A new device, mechanism, or contrivance conceived by the human brain [Ref. 34].

NORMATIVE FORECAST

A forecast based on goals, purposes, objectives, or needs; often self-fulfilling by intention. A normative technological forecast, is a forecast in which future goals and missions are identified and assessed as to technological requirements. Then the process is worked backward to the present, in order to identify the various technological barriers and deficiencies which must be overcome in order to achieve the goals [Ref. 20, 34 and 2].

PLAN

An ordered, definite arrangement or sequence of actions to achieve a specified objective or target [Ref. 34].

RELEVANCE TREE

A logical network similar to a contingency tree, but designed explicitly to elucidate the degree of importance of various "inputs" (e.g., projects) to a broadly defined outcome or goal [Ref. 34].

TECHNOLOGICAL (VIEW POINT)

The view that processes of technological change should be interpreted as being responses to external stimuli (needs, demands, purposes, objectives) [Ref. 34].

TECHNOLOGICAL CHANGE

The advance of technology, such advance often taking the form of new methods for producing existing products and new techniques for organization, marketing, and management [Ref. 5].

TECHNOLOGICAL FORECASTING

Is the probabilistic assessment, on a relatively high confidence level, of future technology transfer [Ref. 20].

TECHNOLOGICAL INNOVATION

The process of perception or generation of relevant science and its transformation into new and improved products and services for which people are willing to pay [Ref. 8].

TECHNOLOGICAL PLANNING

The development of an intellectual concept concerned with the active implementation of technology transfer [Ref. 20].

TECHNOLOGY

The broad area of purposeful application of the contents of the physical, life, and behavioral sciences. It comprises the

entire notion of techniques as well as the medical, agricultural, management and other fields with their total hardware, and software contents [Ref. 20].

TECHNOLOGY ASSESSMENT

Includes forecasting and prediction, retroactive evaluation, and current monitoring and analysis. It involves non-economic, subjective values as well as direct, tangible quantifications [Ref. 35].

TECHNOLOGY TRANSFER

A purposive, conscious effort to move technical devices, materials, methods, and/or information from discovery or development to new use and adoption [Ref. 36].

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APPENDIX B

PRESENT STATUS OF TECHNOLOGICAL FORECASTING TECHNIQUES WITH DETAIL EXPLANATION OF "DELPHI TECHNIQUE"

A. SCOPE OF THE APPENDIX AND INTRODUCTION

The literature of technological forecasting and its utilization during the search phase of this research injects a measure of confusion into the categorization of techniques. Some semblance of standard terminology and definition is just now emerging, but there is enough of what appears to be "Jargon" to scare a novice off, in a state of confusion.

On the other hand it is not in general possible to say which are the best techniques. The best will depend upon the purpose for which the forecast is to be made and the information available. However these techniques may be categorized according to their possible applications, and the situation in which they are particularly useful [Ref. 29].

The problem always exists, because it is to some extent exceedingly difficult to make quantitative statements of future conditions or events. Because of the very uncertainty of the future, human intuition and judgment are as important as any scientific techniques, and this is the main reason which this appendix exphasises the Delphi Technique.

B. APPROACH TO THE VARIOUS TECHNIQUES

Various elements and combinations of the specific technological forecasting techniques can be used in either or both the exploratory and normative senses to explore and plan for the future. According to Siegel, "The key to progress in forecasting is not yet the use of a particular tool. It is, as in other fields of intellectual inquiry, the maintenance of a proper viewpoint -- a viewpoint expressed in witehead's succinct injunction to seek simplicity and also to distrust it." [Ref. 37].

Siegel's words, according to Jantsch [Ref. 20], still characterize the situation today and will be valid for quite some time to come. As previously mentioned in Chapter IV, it may even be generally stated that techniques at present are not developed to replace the "view point" emphasized by Siegel but, rather, to enforce and improve the selection of proper "view points." Even with techniques, technological forecasting today is much more an art than a science.

Jantsch states, the bulk of technological forecasting today is done without the explicit use of special techniques. However, it would be difficult to draw a clear dividing line between use and nonuse. The adoption of a "view point," or a general attitude towards the forecasting problem, structures thinking

and "informed judgment" in a characteristic way, and may imply qualitative or even quantitative relationships between factors [Ref. 20].

C. SPECIFIC TECHNIQUES

There are more than twenty forecasting techniques, and these can be put into categories as follows: [Ref. 27].

1. Intuitive forecasting
   - A. Individual or "genius" forecasting
   - B. Consensus
     - (1) Polls
     - (2) Panels
     - (3) Delphi
2. Trend Extrapolation
   - A. Simple extrapolation
   - B. Curve fitting with judgment modifications
   - C. Trend curves
   - D. Systematic curve fitting
3. Trend correlation
   - A. Pre-cursor events
   - B. Correlation analysis
   - C. Regression analysis
   - D. Correlation coefficient
4. Analogy
   - A. Growth analogy
   - B. Historical analogy [Ref. 2, 9, 20 and 31]

D. DELPHI TECHNIQUE

1. Introduction

In the early 1960's, the Rand Corporation researchers (Helmer and Dalkey) introduced the Delphi technique, designed to improve the use of expert opinion through polling based on three conditions: "Anonimity," "Statistical Display," and "feedback of reasoning." [Ref. 38]. According to Dr. Norman C. Dalkey, the significance of the delphi technique should be examined in the context of what he called the "advice community."

Both industry and government are served by a large group of consultants who purvey information, prediction, and analysis to aid the formation of policy-making decisions [Ref. 38]. The Delphi technique has been chosen for further discussion and more detailed explanations because it has attracted a great deal of popular attention.

2. Delphi Procedures

Delphi is used in forecasting. Contrary to a current belief, it is not a forecasting technique. More properly it should be described as an elegant method for developing a consensus. It is a polling method employed for systematic solicitation of expert opinion [Ref. 9]. The Delphi technique involves the following steps.

a. A typical exercise is initiated by a questionnaire which requests estimates of a set of numerical quantities, e.g.,

dates at which technological possibilities will be realized, or probabilities of realization by given dates, level of performance, and the like.

b. The results of the first round will be summarized, e.g., as the median and interquartile range of the responses, and fed back with a request to revise the first estimates where appropriate.

c. In succeeding rounds, those individuals whose answers deviate markedly from the median (e.g., outside the interquartile range) are requested to justify their estimates. These justifications are summarized, fed back, and counter-arguments elicited [Ref. 38].

The counter-arguments are in turn fed back and additional reappraisals collected. This basic pattern has, of course, many possible variants, only a few of which have been tried. But notice that, "There is no doubt that the delphi method eliminates some of the major objections to the use of committees, which arise largely from psychological factors such as unwillingness to back down from the publicly announced positions, personal antipathy to or excessive respect for the opinions of a particular individual, skill in verbal debate, bandwagon effects, etc." [Ref. 34].

E. CHARACTERISTICS OF THE TECHNIQUES PRESENTED IN THIS APPENDIX

The techniques of technological forecasting, if exercised properly, are based on careful analysis of past experience and require observation, measurement, and interpretation of the underlying data, trends, and interactions associated with the growth of a technology [Ref. 3].

According to Cetron and Ralph [Ref. 2], the success associated with any particular technological forecasting approach is more a matter of expertise in its use and development than of the intrinsic merit of the method selected. In this context, Jantsch states that "He could find no discernible relationship between good forecasting and the use of specific techniques." [Ref. 20]. And also according to Cetron and Ralph, success in technological forecasting really depends on the availability of a good data bank and on the seriousness and dedication with which the effort is undertaken. As a conclusion of this Appendix, it should be noted, that the technique of forecast, whatever it may be, is useful only if it is integrated into a planning and resource allocation system [Ref. 2].

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